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Analysis of Freezing Level Data From Model Output And Radiosonde Ascents

by
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1 Introduction

Freezing level heights over Europe have been calculated from numerical model output and radiosonde ascents. The data has been analysed to compare the forecasting accuracy of the limited area and mesoscale models against sonde observations. Knowledge of the error in forecasting heights of freezing levels is of use when making short-period icing forecasts for aircraft. Accurate forecasting of freezing level heights can also help in predicting bright bands for rain radar correction.

2 Method

Linear interpolation is used to find the freezing level heights for both model and sonde profiles. Using model output, the heights are determined at the position of selected European radiosonde stations. Next the corresponding observed heights from the later radiosonde ascents are noted. All information is stored in archive records. The forecasts assessed are the T+12 valid at 00z and 12z from the limited area model (LAM) and T+12 forecast valid at 12z and T+18 forecast valid at 00z from the mesoscale model. The archive can store up to 3 freezing level heights for each model profile and sonde ascent if there are multiple freezing levels. It is noted whether the temperature lapse at the freezing level is positive or negative. If more than 3 freezing levels are present, then the archive stores the bottom 2 and the top most freezing levels. The cloud amount and the weather during the ascent are also recorded if they are observed.

Data has been accumulated over 15 months from June 1992 to August 1993. During this period, the mesoscale model has been revised. From June 1992 to the middle of December 1992, data is from the old mesoscale model (MES). After December, the data is from the new mesoscale model (NMM).

3 Results

When trying to verify the forecasts, a problem is posed when multiple freezing levels are present in the radiosonde ascent and/or the corresponding forecast from the models. Because of the lack of resolution in the vertical levels of the models, the model profiles may not pick up multiple freezing levels present in the sonde ascent. This causes uncertainty in trying to match the correct freezing level height between the sonde ascent and model forecast. The results shown are for the comparison of radiosonde data and the model forecast where the radiosonde ascent has reported only a single freezing level. By only analysing ascents with one freezing level, we avoid the problem of multiple freezing levels. In most cases the forecast temperature profiles will contain only a single freezing level height. If more than one level has been forecasted, the sonde value is compared with the topmost freezing level height from the model.

Tables 1 and 2 shows the monthly mean, standard deviation (sd) and root mean square (rms) differences (model - sonde). Table 1 is divided into 2 sections. The first section compares the sonde and LAM data from the British Isles. The second section compares sonde data with MES and NMM data. Table 2 compares sonde data from Europe (except the British Isles) with LAM data. Table 3 shows statistics for 3 month and 12 month periods from tables 1 and 2.

The mean monthly differences between the LAM forecasts and the British Isles sonde data in table 1 is negative from June 92 to October 92, less negative or positive (except February 93) from November 92 to May 93 and negative again from June 93 to August 93. This implies the LAM is underestimating the height of the freezing layer from the June to October months by 20-80m on average, while the height forecast is an overestimate for the remaining months except January 93 to March 93. Note that the January and March means although negative are small in magnitude compared to the June to October months mean differences. The February result seems out of place in the Winter/Spring mean differences. Since February was exceptionally anti-cyclonic, the large negative differences could result from underestimation of subsidence warming in the forecasts. The monthly rms differences show less variation compared to the mean differences. They range from 196.89m (March 93) to 269.49m (September 92) with most values centered on about 250m. There is no strong seasonal pattern, but the rms differences do decrease during Spring and increase during the end of Summer and Autumn. This is confirmed by looking at the 3 monthly statistics in table 3. The rms differences for Summer, Autumn and Winter are circa 250m, but for Spring it decreases to 212m. During Summer 93 the mean difference is less negative and the rms difference smaller compared to Summer 92 implying the forecast was generally better.

Results for the mesoscale model forecasts in table 1 are split up into the old mesoscale and the new mesoscale. The MES statistics are significantly different from the LAM values, while the NMM statistics are similar to the LAM values. The monthly mean differences for MES and NMM (combined) follow the same pattern as the British Isles LAM results, i.e. negative during Summer and Autumn and positive for Winter and Spring (with the exception of February 93). Note that the MES values are larger than their LAM counterparts while the NMM values are very similar to the corresponding LAM values (except December 92). The

monthly rms differences for the MES and NMM are greater than the LAM values (except May 93). This may reflect the fact that because there is more structure in the mesoscale temperature profile, there is a greater potential for larger errors. Looking at the MES and NMM rms differences together, they follow the same seasonal variation as the British Isles LAM results. The MES values are significantly worse than the LAM values, while the NMM values are slightly worse. This is shown clearly in the 3 monthly statistics in table 3. A direct comparison between the NMM and MES can be done with the June to August months showing that the NMM performs better than the MES. The NMM has a 3 monthly rms difference of 252m compared to the MES value of 312m and the mean differences in the NMM are generally less negative than the MES results.

The Europe LAM statistics in table 2 has similar trends as the British Isles LAM statistics. The mean difference is negative from June 92 to November 93 and mainly positive for the remaining months, implying, respectively, an underestimate and an overestimate of the freezing level height. The rms differences decrease during the Spring and increase at the end of Summer. The rms statistics are consistently better than the British Isles LAM values except for December 92 and January 93. So the LAM predicts freezing levels over Europe more accurately than over British Isles. The greater accuracy of the LAM over Europe may reflect a tendency for the assimilation of Atlantic weather systems to improve as they move inland over relatively data dense areas. The British Isles observing network is probably too small in extent for this effect to be reflected in the results. The June to August results of 93 have smaller mean and rms differences compared to the same months of 92 suggesting a better forecast. The seasonal statistics in table 3 again follow the same pattern as the British Isles LAM values. The 12 month rms difference (June 92 to May 93) is 225.00m compared with 244.93m for the British Isles.

4 Conclusion

In conclusion, the MES, NMM and LAM show a seasonal variation in the accuracy of forecasts of freezing level height (when verified against sonde ascents reporting only one freezing level). In all the models, the general trend is to underestimate the freezing level height from Summer to Autumn and overestimate for the rest of the year. The monthly rms differences follow a similar pattern for all models, the rms values decreasing during Spring and increasing at the end of Summer and the Autumn. The Europe LAM results are consistently better than the British Isles LAM values. The NMM performs better than the MES. The MES is significantly worse than the corresponding Great Britain LAM while the NMM values are similar to the LAM. The results for Summer 93 (June to August) are generally better than Summer 92. Finally, the archiving of the freezing level heights is an ongoing process and further statistics will be generated in the future.

COMPARISON OF FREEZING LEVELS BETWEEN SONDE DATA AND THE LAM AND MESOSCALE MODEL WHERE THE SONDE DATA HAS ONLY REPORTED A SINGLE FREEZING LEVEL

DIFFERENCE = MODEL LEVEL - SONDE LEVEL
ALL STATISTICS IN METRES
SONDE DATA TAKEN AT 00Z & 12Z
LAM DATA T+12 FORECAST FOR 00Z & 12Z
MESO DATA T+18 & T+12 FORECAST FOR 00Z & 12Z RESPECTIVELY

MONTHLY DATA

GREAT BRITAIN LAM

	MONTH	MEAN DIFF.	S.D. DIFF.	RMS DIFF.	OBS NUM
	JUNE 1992	-76.40	222.45	235.20	511
SUMMER 92	JULY	-73.16	246.38	257.01	518
	AUGUST	-35.25	263.73	266.08	525
	SEPTEMBER	-57.41	263.31	269.49	522
AUTUMN 92	OCTOBER	-24.61	233.53	234.82	362
	NOVEMBER	22.42	256.58	257.56	482
	DECEMBER	21.09	238.52	239.45	174
WINTER 93	JANUARY 1993	-4.40	256.42	256.46	426
	FEBRUARY	-68.22	258.90	267.74	367
	MARCH	-0.71	196.89	196.89	422
SPRING 93	APRIL	17.70	220.76	221.47	478
	MAY	5.16	214.04	214.10	454
	JUNE	-56.72	244.92	251.40	456
SUMMER 93	JULY	-44.27	214.17	218.70	472
	AUGUST	-47.80	238.72	243.46	451

GREAT BRITAIN MESOSCALE MODELS - MES/NMM

	MONTH	MEAN DIFF.	S.D. DIFF.	RMS DIFF.	OBS NUM
	MES	JUNE 1992 to DEC 8th 1992			
	JUNE 1992	-164.39	267.92	314.33	459
SUMMER 92	JULY	-122.27	288.69	313.52	466
	AUGUST	-65.97	302.12	309.23	465
	SEPTEMBER	-96.72	264.92	282.02	448
AUTUMN 92	OCTOBER	-25.79	237.62	239.02	299
	NOVEMBER	18.43	276.37	276.99	421
	DECEMBER	70.68	210.28	221.84	114
	NMM	DEC 24th 1992 to MAY 1993			
	DECEMBER	89.45	287.72	301.31	43
WINTER 93	JANUARY 1993	1.63	260.23	260.23	432
	FEBURARY	-67.93	265.88	274.42	369
	MARCH	5.95	224.66	224.74	421
SPRING 93	APRIL	12.02	225.16	225.48	476
	MAY	11.99	210.09	210.43	447
	JUNE	-89.61	249.55	265.15	453
SUMMER 93	JULY	-56.44	232.68	239.43	472
	AUGUST	-77.09	239.39	251.50	448

Table 1

COMPARISON OF FREEZING LEVELS BETWEEN SONDE DATA AND THE LAM AND MESOSCALE MODEL WHERE THE SONDE DATA HAS ONLY REPORTED A SINGLE FREEZING LEVEL

DIFFERENCE = MODEL LEVEL - SONDE LEVEL
ALL STATISTICS IN METRES
SONDE DATA TAKEN AT 00Z & 12Z
LAM DATA T+12 FORECAST FOR 00Z & 12Z

MONTHLY DATA

	EUROPE LAM MONTH	MEAN DIFF.	S.D. DIFF.	RMS DIFF.	OBS NUM
	JUNE 1992	-35.43	195.81	198.99	3394
SUMMER 92	JULY	-79.94	208.65	223.44	3485
	AUGUST	-98.29	201.72	224.39	3615
	SEPTEMBER	-80.25	216.47	230.87	3427
AUTUMN 92	OCTOBER	-35.07	225.55	228.26	2653
	NOVEMBER	-24.07	233.62	234.85	3080
	DECEMBER	16.09	290.62	291.06	1176
WINTER 93	JANUARY 1993	-63.36	281.54	288.59	2466
	FEBRUARY	-11.36	258.45	258.70	1868
	MARCH	5.84	219.30	219.37	2540
SPRING 93	APRIL	14.41	186.86	187.42	3457
	MAY	10.78	168.40	168.75	3494
	JUNE	1.81	178.77	178.78	3382
SUMMER 93	JULY	-2.67	188.74	188.76	3442
	AUGUST	3.07	186.20	186.22	3452

Table 2

COMPARISON OF FREEZING LEVELS BETWEEN SONDE DATA
AND THE LAM AND MESOSCALE MODEL WHERE THE SONDE DATA
HAS ONLY REPORTED A SINGLE FREEZING LEVEL

DIFFERENCE = MODEL LEVEL - SONDE LEVEL
ALL STATISTICS IN METRES
SONDE DATA TAKEN AT 00Z & 12Z
LAM DATA T+12 FORECAST FOR 00Z & 12Z
MESO DATA T+18 & T+12 FORECAST FOR 00Z & 12Z RESPECTIVELY

3 MONTHLY AND YEARLY STATISTICS

GREAT BRITAIN LAM

PERIOD	MEAN DIFF.	S.D. DIFF.	RMS DIFF.	OBS NUM	
SUMMER 92	-61.42	245.67	253.23	1554	JUN 92-AUG 92
AUTUMN 92	-20.55	255.64	256.46	1366	SEP 92-NOV 92
WINTER 93	-24.04	256.75	257.87	967	DEC 92-FEB 93
SPRING 93	7.76	211.44	211.59	1354	MAR 93-MAY 93
SUMMER 93	-49.54	232.81	238.02	1379	JUN 93-AUG 93
12 MONTHS	-26.00	243.55	244.93	5241	JUN 92-MAY 93

GREAT BRITAIN MESOSCALE MODELS - MES/NMM

PERIOD	MEAN DIFF.	S.D. DIFF.	RMS DIFF.	OBS NUM	
MES	JUNE 1992 to DEC 8th 1992				
SUMMER 92	-117.34	289.48	312.36	1390	JUN 92-AUG 92
AUTUMN 92	-37.06	267.23	269.79	1168	SEP 92-NOV 92
MES PERIOD	-74.22	281.36	290.99	2672	
NMM	DEC 24th 1992 onwards				
WINTER 93	-24.31	267.62	268.73	844	DEC 92-FEB 93
SPRING 93	10.11	220.12	220.35	1344	MAR 93-MAY 93
SUMMER 93	-74.12	240.93	252.07	1373	JUN 93-AUG 93
NMM PERIOD	-3.17	240.15	240.17	2188	DEC 92-MAY 93

EUROPE LAM

PERIOD	MEAN DIFF.	S.D. DIFF.	RMS DIFF.	OBS NUM	
SUMMER 92	-71.87	203.88	216.18	10494	JUN 92-AUG 92
AUTUMN 92	-48.27	226.38	231.47	9160	SEP 92-NOV 92
WINTER 93	-28.78	277.88	279.36	5510	DEC 92-FEB 93
SPRING 93	10.78	189.84	190.15	9491	MAR 93-MAY 93
SUMMER 93	0.73	184.67	184.67	10276	JUN 93-AUG 93
12 MONTHS	-36.14	222.07	225.00	34655	JUN 92-MAY 93

Table 3